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Prepondeance of the Evidence: Tort Rules and the Efficient Standard of Proof *

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Résumé:
Cet article analyse les proprits d'efficience du standard ou degr de preuve requis pour un jugement en responsabilit civile. Dans la common law, le tribunal dcide selon la balance des probabilits en fonction du principe de la prpondrance de la preuve. Nous montrons que, si la production d'information sur le comportement du dfendeur est socialement coteuse, ce standard de preuve est le seul qui soit efficace sur le plan cots-incitations dans un contexte de reponsabilit pour faute.

Abstract:
This paper analyzes the cost and incentive properties of the standard of proof for a finding of negligence. In common law, the usual standard is for courts to decide on the basis of a so-called balance of probabilities or preponderance of the evidence. We show that, if producing information about defendants' behavior is socially costly, preponderance of the evidence is the only cost-and-incentive efficient standard of proof consistent with a negligence rule.

Keywords:
Negligence, preponderance of the evidence, standard of proof, tort rules.

JEL classification: D8, K4

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Dominique Demougin* and Claude Fluet†‡

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Abstract

This paper analyzes the cost and incentive properties of the standard of proof for a finding of negligence. In common law, the usual standard is for courts to decide on the basis of a so-called balance of probabilities or preponderance of the evidence. We show that, if producing information about defendants' behavior is socially costly, preponderance of the evidence is the only cost-and-incentive efficient standard of proof consistent with a negligence rule. [Jel. D8, K4]

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1. Introduction

The present paper analyzes the efficiency properties of standards of proof in tort disputes when the production and processing of evidence about defendants' level of care is socially costly. We show that negligence rules under common law and in the civil code tradition do not have the same properties because they rest on different standards of proof. For unilateral care situations, we examine the set of incentive mechanisms that are consistent with civil procedure. We find that the only cost-and-incentive efficient schemes are either strict liability or negligence together with the standard of proof under common law.

A fundamental institution in common law is that courts rule on the basis of a preponderance of the evidence. For instance, in a tort dispute under the negligence rule, the plaintiff must convince the court that the defendant did not exercise due care.

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The court will decide in favor of the plaintiff on a so-called 'balance of probabilities' or 'preponderance of the evidence'. This means that the defendant is held liable if, on the basis of the evidence, it appears 'more likely than not' that he did not exercise due care. In legal commentary these terms are generally understood as implying a threshold degree of certainty just above 50 percent for a ruling in favor of the plaintiff.[1] For example, in the benchmark ruling *Livanovitch v. Livanovitch,* 99 Vt. 327 131 A. 799 (1926), the court states:

> The slightest preponderance of the evidence in his favor entitle[s] the plaintiff to a verdict. All that is required in a civil case of one who has the burden of proof is that he establish his claim by a preponderance of the evidence. When the equilibrium of proof is destroyed, and the beam inclines toward him who has the burden, however slightly, he has satisfied the requirement of the law, and is entitled to the verdict. "A bare preponderance is sufficient, though the scales drop but a feather's weight."

Preponderance of the evidence stands in sharp contrast to other legal standards of proof such as the 'beyond a reasonable doubt' used in criminal proceedings or the measure of 'clear and convincing proof' employed in equity courts. Moreover, even in the context of civil disputes, the use of preponderance does not generalize to the civilist tradition, although there are some exceptions. For example, Quebec's recently revised civil code makes it clear that its default standard is preponderance of the evidence:

> Evidence is sufficient if it renders the existence of a fact more probable than its non-existence, unless the law requires more convincing proof. (Civil Code of Quebec, Book VII, article 2804)

However, in most countries following the civilist tradition, mere preponderance is not considered sufficient. A case in point is the example of Germany. According to Zöller – a key authority on civil procedure – the German civil standard of proof is not compatible with the common law criterion:

> Less than the conviction of the truth is not sufficient for a proof ... Standards that are based on a measure of likelihood do not find any support in the [*German*] law. (Zöller (1999), p. 812, §286, Rn 18, italics added)

In light of these different standards and contrasting practices across countries some natural questions do arise. Are some civil standards better than others? In what sense do they matter? We address these issues with respect to the cost and incentive properties of tort rules. Specifically, we consider the 'weight of proof' required for a

[1] See Eggleston (1983), Carlson et al. (1997) among others, and the references therein.

finding of negligence in a liability suit. For this purpose, we analyze a situation where negligence has a useful role, as opposed to obviously less costly rules such as strict liability. Under strict liability, an injurer must pay for all accident losses caused to third parties. As is well known, this provides inadequate incentives to exercise care when potential injurers have insufficient wealth to pay damages in full. By contrast, the negligence rule conditions liability both on the occurrence of damages and on the tort-feasor's level of care, observed ex post. Because it relies on more information, such a rule can deter careless behavior even if some potential injurers are partially judgment-proof. However, this result assumes that levels of care are perfectly observable by the court.[2] We therefore extend the analysis of the negligence rule and its comparison to strict liability to the case where ex post information about levels of care is both imperfect and socially costly.

The issues raised are the following. First, whether or not a negligence rule — whatever its standard of proof — can provide greater deterrence than strict liability must depend on the quality or precision of the information used to establish negligence. We show that this requires a threshold information content. Since precision is costly, there is then obviously a trade-off from society's point of view between information costs and the social gains from greater deterrence. Secondly, again because information is costly, it must be used efficiently when negligence is the preferred rule. This means that the standard of proof for a finding of negligence must satisfy well-defined efficiency conditions. We show that this implies the preponderance of the evidence standard. The issues of choosing between tort rules and that of choosing a standard of proof under negligence are therefore interrelated. Specifically, if society is to correctly decide between tort rules on the basis of their respective net benefits, it has to compare strict liability to a negligence rule with a cost-and-incentive efficient standard of proof. Thus, we provide a unifying analysis of the merits of negligence versus strict liability and of the traditional standard of proof in common law.

The argument developed in the paper is straightforward. Starting from a pure mechanism-design point of view, we determine the set of "observables" on the basis of which injurers should be penalized by paying damages to injured parties. For this purpose, the benefits from deterrence and the social cost of producing information about an injurer's actions are taken into account. In our framework, greater deterrence means that more potential tort-feasors are induced to exercise due care. In some cases, the solution to this problem is that no additional information should be produced relatively to merely observing the occurrence of harm. Because the injurer is then always penalized, this is of course equivalent to the strict liability rule. In other cases, the solution is that more information is required so that liability can be conditioned on additional evidence. Due to information costs, this only makes sense if deterrence is thereby greater than under strict liability. In this case, the cost-minimizing mechanism is one where the injurer is penalized if and only if inadequate care is more likely than not; furthermore, the information content of this

[2]See Summers (1983) and Shavell (1986, 1987).

mechanism is such that, under the maximum likelihood decision rule just described, a non-negligent defendant faces a positive probability of escaping liability. This is therefore equivalent to a negligence rule with preponderance of the evidence as its standard of proof.

In the economic literature, the standard of proof has usually been interpreted as the minimum posterior probability for a finding against the defendant.[3] In Davis (1984) and Sanchirico (1997), the efficient standard is that which minimizes the expected social losses from error, where the costs of type I and type II errors (mistakenly penalizing the innocent or not penalizing the guilty) are exogenously given. In Rubinfeld and Sappington (1987) and Hay and Spier (1997), the efficient standard or burden of proof is also examined from the point of view of minimizing litigation expenditures. In Sobel (1985), it is related to the incentives for the parties to disclose costly information. None of these papers singles out the preponderance of the evidence standard.

More in the spirit of our own analysis, Posner (1973), Craswell and Calfee (1986) and Polinsky and Shavell (1989) studied the effect of legal error on the incentives to exercise due care. The trade-off between the cost of greater accuracy in the determination of liability and the degree of deterrence is examined in Kaplow (1994) and Kaplow and Shavell (1994). However, the latter papers do not specifically deal with the issue of the optimal standard of proof. The maximum deterrence property of the preponderance of the evidence standard is derived in Fluet (1999), but that result is not linked to the possibility of minimizing information costs which is at the core of the present paper.

The paper is organized as follows. Section two presents the basic framework and defines generalized liability rules. In section three, we derive the fundamental result regarding efficient rules for assigning liability. In particular, we show that an efficient negligence rule must use preponderance of the evidence as its standard of proof. In section four, we discuss the consequences of other standards of proof. Section five analyzes explicitly the problem of minimizing informational costs and presents the cost-benefit trade-off between tort rules. Section six concludes.

2. TORT RULES

Consider a situation where some agents may impose accidental losses of amount L on third parties. The probability of harm depends only on the potential injurers' level of care, which can take two values referred to as high and low care with opportunity cost $c_0 > c_1$ and probability of accident $p_0 < p_1$ respectively. Tort-feasors differ in their wealth or liability limit w distributed according to the cdf $H(w)$, with $H(w) > 0$ for all $w > 0$. For the sake of the analysis, all individuals are risk neutral and high care is the socially efficient action, that is

$$p_0 L + c < p_1 L \quad \text{where } c = c_0 - c_1 \,. \tag{1}$$

[3]The Bayesian approach is also typical of the statistical legal literature (e.g. Fienberg, 1988). One problem with this approach is that one does not know how the court's priors are initially formed.

Under the *strict liability* rule, an injurer is held liable for any harm he may cause. This means that an injurer pays either L or his liability limit if the latter is smaller. Therefore, for an agent with wealth w, private incentives to take care are aligned with those of society if

$$p_0 \min[w, L] + c \leqslant p_1 \min[w, L] . \tag{2}$$

Under this rule, the critical wealth threshold at which potential injurers are just indifferent between either care levels is

$$w_S = \frac{c}{p_1 - p_0} , \tag{3}$$

which implies that a proportion $H(w_S)$ of potential tort-feasors exerts inadequate care.

Under the *negligence* rule, in addition to ascertaining the occurrence of an accident, courts consider additional information about the injurer's level of care. A defendant is then held liable if the court is satisfied, on the basis of the evidence, that he did not exert due care (courts are assumed to equate due care with the socially efficient level). Just as before, liability means that the injurer reimburses the loss fully as far as his wealth allows. An essential characteristic of the negligence rule is that, by contrast with strict liability, injurers exerting adequate care face a strictly positive probability of being exonerated.

In the context of the negligence rule, a trial is therefore a fact finding procedure or "experiment" where evidence is made available to the court and a decision regarding liability is taken on the basis of that information. The evidence produced in court is usually complex and multidimensional. Accordingly, we represent potential evidence by a random vector $X \in \mathbb{R}^n$ with conditional density functions $f_0(x\,|\,e)$ and $f_1(x\,|\,e)$, depending on the actual level of care exerted by the injurer[4], and where e reflects the inputs in the production and processing of evidence about injurers' behavior. For parsimony, we equate e to the social costs of generating information[5].

For some realization of the evidence, the defendant is declared negligent and held liable. Otherwise, the court decides against the plaintiff and the defendant is not required to cover any of the damages. The court's decision rule may be described analytically by a function φ, with $\varphi(x) = 1$ when the defendant is pronounced negligent and $\varphi(x) = 0$ otherwise. Since φ describes the court's ruling on the basis of the evidence, it implicitly reflects the *standard of proof* for a finding of negligence.

Potential injurers know the legal environment. They are aware that in the case of an accident evidence about their care level will be gathered and presented at a trial. They understand the courts' decision rule and can infer the probabilities of being

[4]Since f_0 is conditional on the occurence of an accident, it is not defined when $p_0 = 0$. Obviously, in that case an accident perfectly reveals care (*res ipse loquitur*).

[5]Alternatively, one could introduce vectors of prices and inputs and minimize costs subject to a given level of informativeness (see Demougin and Fluet (1998) for a similar appoach in a principal-agent problem).

found negligent. As a result, an agent with wealth w is led to exercise due care if

$$\{p_0 \int \varphi(x) f_0(x\,|\,e)\,dx\} \min[w, L] + c \leqslant \{p_1 \int \varphi(x) f_1(x\,|\,e)\,dx\} \min[w, L]\ . \qquad (4)$$

In the current setting, strict liability and negligence are the only rules observed in most countries. However, different schemes are *a priori* conceivable. From a more abstract perspective, a tort rule is simply an incentive mechanism subject to particular restrictions: first, the scheme relies only on post-accident information; second, incentives can only be provided through sanctions; third, penalties are monetary and correspond to an allocation of damages between the parties; and fourth, the rule is the same for all individuals (e.g. the kind of rule employed is not conditioned on the injurer's wealth). Consistent with these properties, we define a *general liability scheme* as an input level e in the production and processing of evidence – generating the information system $\{f_0(x\,|\,e), f_1(x\,|\,e)\}$ – and a penalty function $s(x)$ satisfying

$$0 \leq s(x) \leq \min[w, L]. \qquad (5)$$

The constraints on the penalty function can be equivalently represented as $s(x) = \varphi(x) \min[w, L]$, where $\varphi(x)$ can now take any value on the interval $[0, 1]$. Obviously, the standard tort rules described above are a special case of the general liability scheme:

- *Strict liability* is given by the scheme $e = 0$ and $\varphi(\cdot) \equiv 1$. Due to $e = 0$, the post-accident evidence is assumed to be perfectly uninformative with $f_0 \equiv f_1$.
- *Negligence rules* are characterized by $e > 0$ and $\varphi(x) \in \{0, 1\}$ together with $\int \varphi(x) f_0(x\,|\,e)\,dx < 1$. The latter condition reflects the requirement that individuals who undertake due care must face a positive probability of escaping liability.

Under such a generalized scheme, the condition for an agent to exercise due care is the same as in (4), though φ is now more general. The resulting critical wealth threshold is therefore

$$w_G = \frac{c}{p_1 \int \varphi(x) f_1(x\,|\,e)\,dx - p_0 \int \varphi(x) f_0(x\,|\,e)\,dx} \qquad (6)$$

and a proportion $H(w_G)$ of potential injurers undertakes inadequate care.

From society's point of view, the optimal liability scheme is the one which minimizes the overall sum of care costs, accident losses and information or administrative expenditures. In the present context, information expenditures refer to the ex post expenses in producing and assessing evidence about injurers' behavior. For parsimony, all other sources of information and administrative costs are assumed to be zero. Society's optimization problem is therefore to choose the level of information costs e and the decision rule $\varphi(x)$ solving

$$\min_{e \geq 0, \varphi(x) \in [0,1]} SC \equiv [1 - H(w_G)]c + [p_0(1 - H(w_G)) + p_1 H(w_G)](L + e), \qquad (7)$$

where w_G is determined as above.

3. PREPONDERANCE OF THE EVIDENCE

For any level of information costs, it is clear from society's optimization problem that φ should be chosen so as to keep w_G as small as possible, thereby maximizing the proportion of individuals exerting due care. From (6) this is equivalent to solving

$$\max_{\varphi(x)\in[0,1]} \delta \equiv \int \varphi(x)[p_1 f_1(x\,|\,e) - p_0 f_0(x\,|\,e)]\,dx\ , \tag{8}$$

where δ captures the level of deterrence. The following result is then straightforward.

Lemma 1. *For a given e, let φ_e denote the penalty scheme that maximizes deterrence. Then, it must satisfy*

$$\varphi_e(x) = \begin{cases} 1 & \text{when } p_1 f_1(x\,|\,e) > p_0 f_0(x\,|\,e) \\ 0 & \text{when } p_1 f_1(x\,|\,e) < p_0 f_0(x\,|\,e) \end{cases} \tag{9}$$

A φ_e-scheme assigns liability on the basis of a maximum likelihood criterion with respect to all available information, where the latter includes the occurrence of an accident and the additional evidence about the defendant's care level. That is, the injurer should be held liable if careless behavior is ex post more-likely-than-not; conversely, he should escape liability when adequate care is more likely. When the evidence is such that both levels of care are equally likely, the assignment of liability is a matter of indifference.

Observe that there might be some realizations of evidence where the court has complete certainty about the injurer's behavior. For instance, when $f_0(x\,|\,e) = 0$ and $f_1(x\,|\,e) > 0$, a court hearing x would know for sure that the injurer has been careless. To maximize deterrence, the injurer should be held liable. Similarly, if $f_0(x\,|\,e) > 0$ and $f_1(x\,|\,e) = 0$, the injurer would be known to have taken adequate care and should consequently not be required to cover any of the damages. The lemma uses a more-likely-than-not criterion to extend these 'common sense' liability assignment rules to situations with uncertainty about the defendant's behavior.

Given the above comments, we focus *without loss of generality* on the sanction scheme φ_e^* defined by $\varphi_e^*(x) = 1$ when $p_1 f_1(x\,|\,e) > p_0 f_0(x\,|\,e)$ and $\varphi_e^*(x) = 0$ otherwise. We do that because this captures what is commonly understood as the preponderance of the evidence standard. Although this seems to suggest that deterrence is maximized by a negligence rule with preponderance, the conclusion does not quite follow. The reason is that for some $e > 0$ we may have $\varphi_e^*(\cdot) \equiv 1$, thereby requiring the injurer to pay whenever an accident occurs irrespective of the additional evidence. For this peculiar case deterrence is the same as under the strict liability rule, i.e. $\delta_S = p_1 - p_0$.

Lemma 2. *The liability scheme (e, φ_e^*) provides greater deterrence than strict liability if and only if*

$$\Pr[p_0 f_0(X\,|\,e) > p_1 f_1(X\,|\,e)\,|\,c_0] > 0\ . \tag{10}$$

Proof. Let $E = \{x \,|\, p_0 f_0(x \,|\, e) > p_1 f_1(x \,|\, e)\}$. Then the claim follows by noting that deterrence greater than under strict liability is equivalent to

$$p_0 \int_E f_0(x \,|\, e)dx > p_1 \int_E f_1(x \,|\, e)dx$$

where

$$\Pr[E \,|\, c_0] = \int_E f_0(x \,|\, e)dx \ .$$

■

The condition in the lemma is a statement about the informational content of the evidence. To see the intuition of the result, suppose a statistician were to learn about the occurrence of an accident. Without any further evidence, owing to $p_1 > p_0$, he would conclude that it is more likely that the injurer did not undertake due care. What if additional evidence is acquired? In the instance where the added observations have a weak informational content the statistician would still find it more likely that the defendant was careless, whatever the actual realization of the evidence. Thus, condition (10) can only be satisfied if the informational content of the evidence is above a certain threshold.[6]

In the next section, we further analyze the relationship between informational content and standard of proof. However, a central result of the paper can already be derived by observing that it is costly to produce and process evidence. Indeed, since strict liability generates deterrence δ_S at zero costs, efficiency requires that evidence costs be incurred only if it raises deterrence above that level. From lemma 1, we know that the optimal penalty scheme takes the form φ_e^*. According to lemma 2, φ_e^* has deterrence greater than δ_S only if $\int \varphi_e^*(x) f_0(x \,|\, e)dx < 1$. The latter condition is not compatible with $e = 0$ (which implies $f_0 \equiv f_1$). Hence information costs must be strictly positive. Altogether, these observations lead to the following proposition.

Proposition 1. *The only efficient liability schemes are either strict liability or the negligence rule with the 'preponderance of the evidence' standard of proof.*

The preceding result is a normative statement about efficient liability rules. The proposition clarifies that legal systems concerned with cost efficiency should only use either strict liability or the negligence rule together with the preponderance of the evidence. Which of the two rules is better can only be determined by a cost-benefit analysis of the trade-off between informational expenditures and deterrence.

4. NEGLIGENCE WITH OTHER STANDARDS OF PROOF

As discussed in the introduction, 'preponderance of the evidence' is the default standard of proof for civil disputes in common law countries, but other standards are also observed in some legal systems. For instance, countries in the German legal tradition

[6] Lemma 2 may capture the idea of "sufficient evidence" as discussed for instance in Tribe (1971).

(e.g., Austria, Germany and Sweden) use a stronger standard than 'preponderance of the evidence' for a finding of negligence. From the foregoing section, we already know that doing so cannot be socially efficient since it leads to less deterrence than would otherwise be possible, given the quality of the evidence. Moreover, for some standards of proof, a negligence rule may actually provide less deterrence than strict liability.

In order to explore this issue more fully, we model other standards of proof by introducing the idea of coherence of judgments. Specifically, consider the use of a negligence rule where e is spent on the production of information. In that context, suppose a court holds a defendant liable after observing the evidence $\widehat{x}$. Then, coherence demands that the court also reaches the same conclusion upon hearing x, where

$$\frac{p_1 f_1(x\,|\,e)}{p_0 f_0(x\,|\,e)} \geqslant \frac{p_1 f_1(\widehat{x}\,|\,e)}{p_0 f_0(\widehat{x}\,|\,e)}\,. \tag{11}$$

This follows because given (11) inadequate care is at least as likely upon observing x as it is under $\widehat{x}$. Accordingly, a standard of proof is consistent when a defendant is held liable if $p_1 f_1(x\,|\,e) > k p_0 f_0(x\,|\,e)$ and non-liable if $p_1 f_1(x\,|\,e) < k p_0 f_0(x\,|\,e)$, where k is the critical likelihood ratio characterizing the particular standard. Preponderance of the evidence satisfies these requirements for $k = 1$, whereas $k > 1$ yields a stronger standard. By contrast, with $k < 1$ less convincing evidence is sufficient.

The condition for consistency corresponds to the requirements of a most powerful test in statistics. To see this, consider a randomized procedure to test the hypothesis of high versus low care. Upon observing x, the procedure either rejects or accepts the hypothesis of high care with probability $\psi(x)$ and $1-\psi(x)$ respectively. Let α and β denote the significance level and the power of the test,

$$\alpha = \int \psi(x) f_0(x\,|\,e)\,dx \quad \text{and} \quad \beta = \int \psi(x) f_1(x\,|\,e)\,dx\,. \tag{12}$$

From Neyman-Pearson's fundamental lemma, maximizing power for a given significance level implies a rejection rule satisfying the above consistency condition for some k.[7] Of course, when $\alpha < 1$, the resulting ψ is equivalent to a negligence rule.

Letting $\beta(\alpha, e)$ denote the resulting power function deterrence becomes

$$\delta(\alpha, e) = p_1 \beta(\alpha, e) - p_0 \alpha, \qquad \alpha \in [0,1]\,. \tag{13}$$

The main advantage of introducing such a deterrence function via Neyman-Pearson's lemma is that we can use basic probability theory to derive the following result.

Lemma 3. *The deterrence function $\delta(\alpha, \cdot)$ is concave and piece-wise differentiable with $\delta_\alpha(\alpha, \cdot) = p_0(k-1)$, where k is the corresponding critical likelihood ratio. Furthermore,*

$$(p_1 - p_0)\alpha \leq \delta(\alpha, \cdot) \leq p_1 - \alpha p_0, \qquad \alpha \in [0,1]\,, \tag{14}$$

[7] That is, $\psi(x) = 1$ if $p_1 f_1(x\,|\,e) > k p_0 f_0(x\,|\,e)$ and $\psi(x) = 0$ if $p_1 f_1(x\,|\,e) < k p_0 f_0(x\,|\,e)$. When the set where the equality holds has positive measure, the critical function can also be zero-one in such a way as to satisfy α.

with $\delta(\alpha, \cdot) \equiv (p_1 - p_0)\alpha$ *if and only if* $f_0 \equiv f_1$.

Proof. See appendix.

Figure 1 maps deterrence functions according to the standard concept of informativeness.. As is well known, the statistical definition of a *more informative* experiment is that it allows more power for all significance levels.[8] Consequently, in the current setting more informative evidence increases deterrence for all values of α.

The lines labeled q and u depict the extreme cases where the post-accident evidence contains either no or perfect information. Analytically, q and u are given by the right and left hand side of (14) respectively. In the instance illustrated by q, courts have no relevant information beyond the occurrence of accident. Deterrence is then maximized by $\alpha = 1$, which corresponds to strict liability. At the other extreme, with perfect information the maximum is reached at $\alpha = 0$ and $\beta = 1$. This is the case usually discussed in the literature. Here negligence clearly produces more deterrence than strict liability.

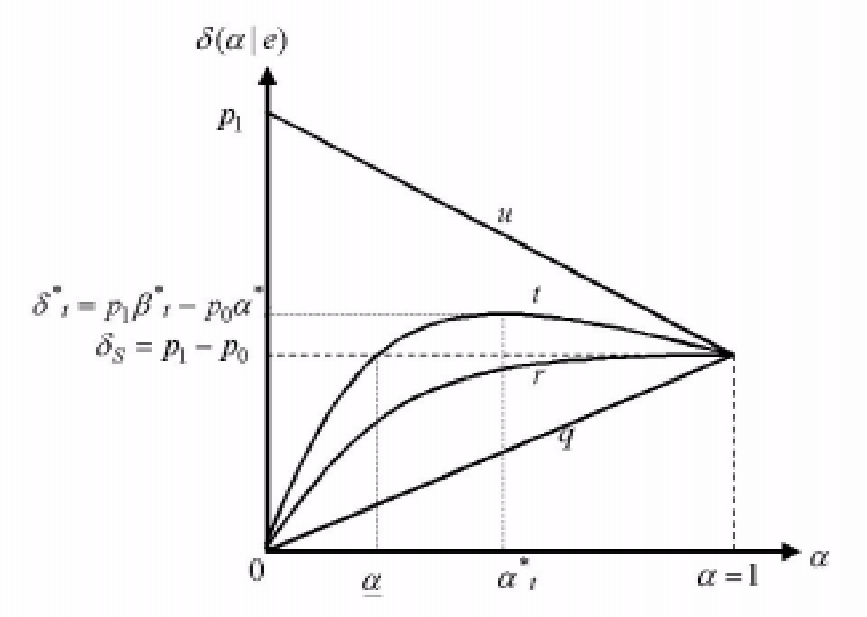

Fig.1: Deterrence functions

In the figure, two additional information systems have been represented. The system labeled r cannot be efficient if information is costly. This is the peculiar case discussed earlier where evidence is informative but not sufficiently so. Maximal deterrence remains at δ_S just as under the less expensive regime of strict liability.

[8]This definition is equivalent to the statement that less informative variables can be obtained by adding noise to more informative ones (Blackwell, 1953). In terms of f_0 and f_1, more informative is equivalent to a mean preserving spread of f_1/f_0 considered as a random variable. See Demougin and Fluet (1999) for an example of these equivalence results in a more general principal-agent problem.

By contrast, under information system t deterrence is maximized at $\alpha_t^* < 1$, leading to $\delta_t^* > \delta_S$. Applying the results from the foregoing section, such a deterrence level requires negligence with preponderance of the evidence. That the optimal standard of proof is preponderance also obtains from lemma 3 by observing that an interior solution implies $\delta_\alpha(\alpha_t^*, e_t) = 0$, which occurs for $k = 1$.[9]

Figure 1 allows a straightforward analysis of the incentives induced by other standards of proof. From the lemma, α is non-increasing in k. Now consider a situation where the information system is represented by t. For some $k > 1$, the significance level will be smaller than $\underline{\alpha}$. Under such a standard, the negligence rule produces less deterrence than strict liability, despite higher information costs due to the necessity of acquiring and processing evidence.

This underlines the importance of carefully characterizing negligence rules in terms of their standard of proof when comparing liability regimes across countries. The following positive statement underscores this point.

Proposition 2. *Consider a negligence rule with a k-standard of proof (i.e. under the standard some defendants are observed to escape liability). If $k \leqslant 1$, then deterrence is as at least as large as under the strict liability rule. For $k > 1$ this result cannot be guaranteed.*

Proof. With a k-standard of proof the defendant is held liable if $p_1 f_1(x \,|\, e) > k p_0 f_0(x \,|\, e)$ and non-liable otherwise. Let $\alpha(k)$ denote the resulting significance level. Since some defendants are found non-negligent, $\alpha(k) < 1$. If $k \leqslant 1$, $\alpha^* \leqslant \alpha(k) < 1$, where α^* maximizes $\delta(\alpha, e)$. Recalling that $\delta(1, e) = \delta_S$, the concavity of the deterrence function then implies $\delta(\alpha(k), e) \in [\delta_S, \delta(\alpha^*, e)]$. A case with $k > 1$ is discussed above and illustrated in the figure. ■

The proposition guarantees that under common law the negligence rule generates at least as much deterrence as strict liability. This stands in sharp contrast with those civil law systems where the standard of proof for a finding of negligence is stronger than preponderance (i.e. $k > 1$). Here observing that not all defendants are held liable does not preclude a level of deterrence lower than δ_S.[10]

5. MINIMIZING INFORMATION COSTS

In this section, we examine more formally the implication of raising the informational quality of evidence. Since acquiring more accurate evidence should raise society's informational costs, we impose the following condition.

ASSUMPTION: For any $e \geq 0$, $\beta(\alpha, e)$ is continuous and nondecreasing in e, with $\beta(\alpha, 0) = \alpha$.

[9] Strictly speaking, the argument requires that $\delta_\alpha(\alpha_t^*, e_t)$ exists. However, even when it does not $k = 1$ remains a solution.

[10] Interestingly, countries like Germany which use a strong standard for a finding of negligence, often reverse the burden of proof. Though this is beyond the scope of the current model, intuition suggests that it could be equivalent to $k < 1$, thereby guaranteeing deterrence larger than δ_S.

The foregoing discussion regarding the standard of proof can now be reinterpreted in terms of informational costs. Suppose society wants to attain deterrence level $\overline{\delta} > \delta_S$. As can be seen from figure 2, any standard other than preponderance of the evidence implies spending more resources on gathering and processing evidence.

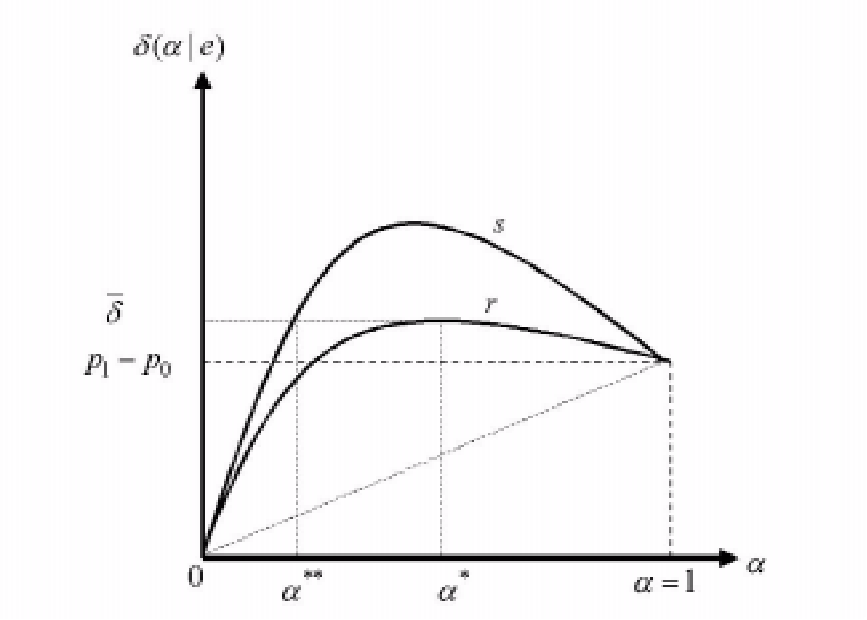

Fig. 2: Minimizing information costs

This suggests a reinterpretation of proposition 1. In our derivation, the efficiency of the preponderance standard under negligence was obtained by observing that, for any level of information costs, maximizing deterrence is a necessary condition for solving the overall optimization problem. However, if all tort-feasors have wealth greater than some $\underline{w} > 0$ (i.e. $H(\underline{w}) = 0$), the same logic does not hold. For example, using figure 2, suppose $\overline{\delta}$ were enough to induce all participants to undertake efficient care. Then with system s the standard of proof generating α^{**} would also align all individual incentives, even though it does not maximize deterrence. However, that combination would not be efficient because society can obtain the same behavior from potential injurers by using the less informative and less costly system r together with α^*, that is together with preponderance of the evidence.

Proposition 3. *The only schemes minimizing information costs for the level of deterrence achieved are either strict liability or the negligence rule together with preponderance of the evidence.*

To conclude, we briefly discuss the cost-benefit comparison of strict liability and negligence. Recall that efficiency considerations require that a negligence rule always provides greater deterrence. Since this implies a threshold level of information costs,

there is consequently a non-convex trade-off between the additional costs and the benefits from greater deterrence.[11]

Under strict liability a proportion $H(w_S)$ of potential injurers exert inadequate care, where $w_S = c/(p_1 - p_0)$. Under a negligence rule, the proportion of careless individuals is $H(w_N)$ where $w_N = c/\delta$. The gross benefits from using negligence rather than strict liability are then

$$B(\delta) = [H(w_S) - H(w_N)]\,[(p_1 - p_0)L - c]\,, \tag{15}$$

the increased proportion of agents exercising socially efficient care times the net benefits from that care. This expression tends to zero as δ approaches $p_1 - p_0$ and it is otherwise increasing in deterrence, at least up to the point where all agents are induced to undertake socially optimal care.

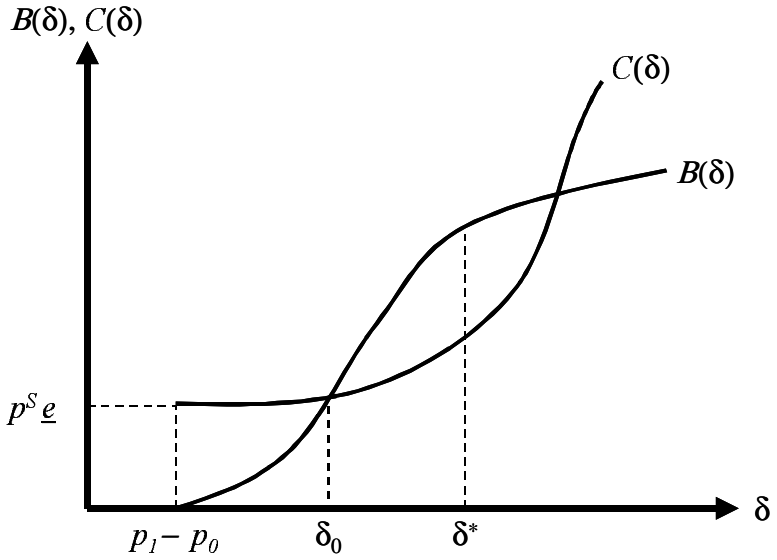

Figure 3: Cost-benefit comparison of tort rules

Since the cost of strict liability is zero in the present analysis, $e(\delta)$ may be interpreted as the additional costs incurred under an efficient negligence rule as a function of the level of deterrence it provides. Writing these costs as per-accident expenditures, the cost of negligence compared to strict liability is therefore

$$C(\delta) = [p_0 + (p_1 - p_0)H(w_N)]\; e(\delta), \tag{16}$$

the average probability of accident under negligence times the additional per-accident expenditures under that rule. The expected number of accidents is decreasing in

[11] Non-convexity is a well known characteristic of the value of information in the standard decision theoretic context (cf. Radner and Stiglitz, 1984).

deterrence while $e(\delta)$ is increasing, so that $C(\delta)$ may be either increasing or decreasing. However, we know that as δ decreases to $p_1 - p_0$, the costs tend to

$$p^S \underline{e} = [p_0 + (p_1 - p_0)H(w_S)] \underline{e} > 0,$$

the expected number of accident under strict liability times the per-accident cost threshold under negligence – denoted by $\underline{e}$.

A negligence rule with a deterrence level δ is better than strict liability if $C(\delta) < B(\delta)$. In figure 3, this corresponds to a situation where the gathering and processing of evidence under negligence is sufficiently informative to provide deterrence greater than δ_0. In the figure, the best situation is in fact a negligence rule with level of informativeness associated with deterrence δ^*.

Of course, if the cost curve were always above the gross benefit curve, then the best rule would be strict liability. Thus, negligence makes sense only if there is a threshold increase in deterrence and only if the information costs that this implies are worth the benefits from greater deterrence.

6. CONCLUDING COMMENTS

Our analysis allows some strong conclusions. First, the negligence rule as usually understood under common law – with preponderance of the evidence and a positive probability of escaping liability for non-negligent defendants – satisfies a necessary condition for cost-efficiency. Specifically, for the level of deterrence that it provides, the rule minimizes informational requirements; if the process by which information is produced is not itself wasteful, then the rule minimizes information costs for the level of deterrence achieved. Secondly, negligence together with preponderance never provides less deterrence than strict liability. In fact, this conclusion depends crucially on preponderance and does not extend to stricter standards of proof, such as those usually required within the civilist tradition.

Our findings contrast with known results on the properties of a negligence rule when the defendants' care is imperfectly observable. For example, in Craswell and Calfee (1986) and Shavell (1987) tort-feasors are not wealth constrained. It is shown that with a negligence rule both under and overproduction of care are possible relative to the first-best. From our analysis, underprovision of care would not be possible if negligence is defined in terms of preponderance of the evidence. This follows because negligence then generates at least as much deterrence as strict liability, which already attains the first-best in such a context.

However, that literature also raises the issue of overdeterrence. In our model, the problem cannot arise since by assumption there are only two possible levels of care. Suppose however we were to introduce an additional level assumed to be excessive compared to the first-best, yet keep the solution unchanged at e^* and $k = 1$. Would overproduction be possible in such a situation? It is easy to construct cases where it could obtain for agents with wealth over a certain level. As a result, a trade-off would now exist between aligning the incentives of the least wealthy and overdeterring the rich. How would the optimal mechanism adjust? In particular, what would be

the effect on the standard of proof? A complete answer is beyond the scope of this paper, mainly because it would require additional assumptions with respect to the characteristics of information systems. Moreover, one difficulty which now arises is that due care may diverge from the first-best solution. For instance, suppose that "excessive" care is perfectly revealed ex post at no additional costs. Society might then gain by implementing that level, thereby saving all information costs. Thus, we have altogether a complex trade-off between the choice of care, information costs and deterrence.

We conclude with two remarks. First, in our analysis, the production of evidence is treated as a black box. It is clear that one may enquire whether the process by which evidence is produced is itself efficient. This process involves the defendant and the plaintiff, as well as the court system itself, including rules of procedure, the role and quality of court officials, etc. Some of the problems this raises are addressed in the literature. For instance, it has recently been suggested that an adversarial system might be an efficient way of producing evidence, as opposed to non partisan procedures.[12]

Finally, we have analyzed a case where negligence may be better than strict liability because some agents have limited solvency. There are other cases, for instance the so-called bilateral care situation where the probability of harm depends on the actions of both the potential injurer and potential victim. The traditional negligence rule here is for the injurer to be liable only if shown negligent, while the victim is not deemed negligent. Another efficient rule for this case, at least under perfect information, is strict liability on the injurer with a defense of contributory negligence with respect to the victim's behavior. An extension of the present analysis is to examine whether these rules are equivalently efficient when information is costly, and whether preponderance of evidence remains the cost-efficient standard of proof in this context.

APPENDIX

Before proving lemma 3, we make the following claim:

Claim. *For any e, let $\psi(x)$ be the critical function of a most powerful test of size $\alpha \in (0,1)$. Then*

$$\psi(x) = \begin{cases} 1 & \textit{when} \quad f_1(x \mid e) > \beta_\alpha^-(\alpha, e) f_0(x \mid e) \\ 0 & \textit{when} \quad f_1(x \mid e) < \beta_\alpha^-(\alpha, e) f_0(x \mid e) \end{cases} \tag{A1}$$

where the conditions on ψ are taken to hold a.e. and $\beta_\alpha^-(\alpha, e)$ denotes the left hand derivative.

[12] This is argued in Dewatripont and Tirole (1999). See also Milgrom and Roberts (1986) and Shin (1998), as well as other references quoted in the introduction.

Proof of claim. *By definition:*

$$\alpha = \int \psi(x) f_0(x \mid e)\, dx \text{ and } \beta(\alpha, e) = \int \psi(x) f_1(x \mid e)\, dx. \tag{A2}$$

From basic probability theory[13], $\beta(\alpha, e)$ *is nondecreasing and concave in* α*; from these properties,* $\beta(\alpha, e)$ *is piece-wise differentiable in* α*. Now, suppose the first statement is not true. Let*

$$\widehat{\psi}(x) = \begin{cases} 1 & when \quad f_1(x \mid e) > \beta_\alpha^-(\alpha, e) f_0(x \mid e) \\ \psi(x) & otherwise \end{cases}, \tag{A3}$$

thus,

$$\int (\widehat{\psi} - \psi) f_1\, dx > \beta_\alpha^-(\alpha, e) \int (\widehat{\psi} - \psi) f_0\, dx \equiv \beta_\alpha^-(\alpha, e)\varepsilon \tag{A4}$$

where $\varepsilon \geq 0$*. Noting that* $\widehat{\psi}$ *is a critical function of size* $\alpha + \varepsilon$*,*

$$\beta(\alpha + \varepsilon, e) \geq \int \widehat{\psi} f_1\, dx = \beta(\alpha, e) + \int (\widehat{\psi} - \psi) f_1\, dx > \beta(\alpha, e) + \beta_\alpha^-(\alpha, e)\varepsilon. \tag{A5}$$

Since concavity requires $\beta_\alpha^-(\alpha, e) \geq \beta_\alpha^+(\alpha, e)$*,*

$$\beta(\alpha + \varepsilon, e) > \beta(\alpha, e) + \beta_\alpha^+(\alpha, e)\varepsilon. \tag{A6}$$

If $\varepsilon = 0$*, this is a contradiction; if* $\varepsilon > 0$*, the result is incompatible with the concavity of* β in α*.*

If the second statement does not hold, then a similar argument leads to

$$\beta(\alpha - \varepsilon, e) > \beta(\alpha, e) - \beta_\alpha^-(\alpha, e)\varepsilon \tag{A7}$$

where $\varepsilon \geq 0$*. Again, this is either contradictory if* $\varepsilon = 0$ *or incompatible with concavity if* $\varepsilon > 0$*.* ■

Proof of lemma 3. *The concavity and piece-wise differentiability of* $\delta(\alpha, \cdot)$ *follow directly from the same properties of* $\beta(\alpha, \cdot)$*. From the foregoing claim, if* k *is any critical likelihood ratio for a test of size* α*, then* $\beta_\alpha^-(\alpha, e) \geq k \geq \beta_\alpha^+(\alpha, e)$*. Thus, whenever* $\beta_\alpha(\alpha, e)$ *exists* $\delta_\alpha(\alpha, e) = p_0(k - 1)$*. Finally, given the assumption of density functions,* $\beta(1, e) = 1$ *and* $\alpha < \beta(\alpha, e) \leqslant 1$ *for all* $\alpha \in (0, 1)$*, unless* $f_0 \equiv f_1$ *in which case* $\beta = \alpha$ *for all* α*.* ■

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[13] See for instance Lehmann (1986).

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